A Barometer Element for Radio-Sondes*

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The barometer unit described herein has proven to be extremely reliable when used on balloon flights to high altitudes. It consists of an aneroid element which moves an arm, making a series of contacts with no mechanical amplification involved. Working on the digital principle it gives its information when certain definite pressures have been reached.

I. INTRODUCTION

MANY experiments with balloons demand a precise measurement of air pressure to relate to temperature of the air, humidity, cosmic rays, etc. For cosmic-ray experiments with ionization chambers, for example, an error of 1 mm of Hg pressure corresponds to an error of 1 percent in ionization at the steepest part of the ionization-depth curve. Since ionization measurements can now be made at high altitudes with errors somewhat less than 1 percent[1] it becomes important to know the mass of air overhead to better than 1 mm of Hg. It was found that where mechanical amplification is used, frictional effects together with other uncertainties resulting from play in bearings, bending of parts, etc., often introduced rather large and unpredictable errors in pressure measurements, which become quite important at low pressures.

In the instrument here described the straight expansion of a bellows was used, thus simplifying construction as well as eliminating many of the inherent difficulties often encountered where mechanical amplification is employed.

II. DESCRIPTION OF THE INSTRUMENT

In Fig. 1 is reproduced a photograph of the bellows and mounting. The bellows is made by Kollsman Instrument Company and is the one used in their aircraft altimeter. It has the property of expanding more for a given change in pressure at low pressures than at high pressures. This characteristic, together with the mechanical amplification used, gives a scale for the altimeter which is linear with height. The actual expansion of the bellows for a change of 1 atmosphere pressure is about 7 mm.

The free end of the bellows as shown in Fig. 1 is quided by a phosphor-bronze strip, A, that gives rigidity in all directions except one. The contact C is of platinum, bent back on itself to form a smooth, rounding surface and is mounted on a phosphor-bronze strip fastened to the bellows.

The platinum contact rubs on a set of four small wires wound on a piece of ceramic tubing. The four wires are all insulated from each other and are wound simultaneously on a lathe with a pitch which is four times that needed if only one wire were being wound. The method is illustrated schematically in Fig. 2. Thus as the contact C, which is actuated by the bellows, moves along, every fourth wire passed over is the same.

In practice a long piece of ceramic tubing was wound with nickel wire 0.025 cm in diam with a spacing of 0.032 cm between centers of turns. Before coating with a good insulating varnish, a narrow strip of adhesive tape was placed on the winding from one end to the other to keep the varnish from covering the section of the wires where electrical contact was to be made later. After baking on a thick coating of varnish, the ceramic tubing with its windings was cut into sections about 2 cm long. The four wires at one end were unwound a few turns and were later soldered to the terminal strip as shown in Fig. 1. The section of ceramic tubing was cemented to an inner core of Bakelite rod that was fastened rigidly to two supports which in turn were secured to the aluminum baseplate.

As the bellows expands, it first makes contact with one wire, then the next, until four have been passed over; then it repeats. By knowing the sequence of the contacts, it is possible to determine whether the pressure is increasing or decreasing. To give an additional coding, two adjacent wires of the quadruple winding were fastened together.

There is the possibility of an uncertainty of position of the contact, since each set of four contacts is the same

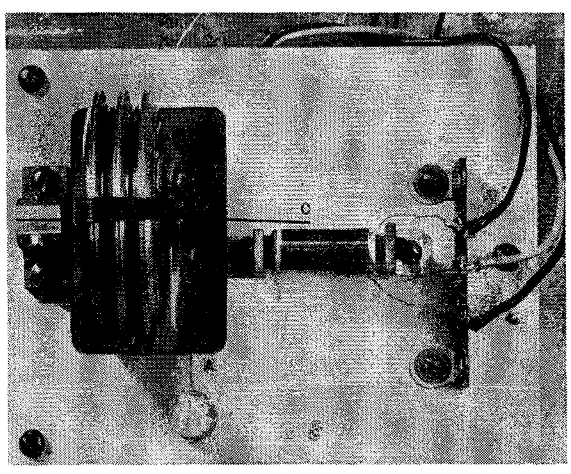

FIG. 1.

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[1] See following article on a new type of ionization chamber, Rev. Sci. Instr. 24, 99 (1953).

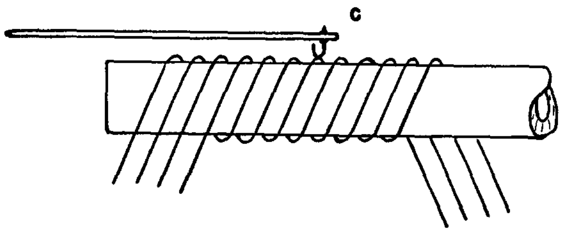

FIG. 2.

as every other set. However, a knowledge of the calibration and the ground pressure always gives a unique answer.

For a change of one atmosphere, approximately 20 barometer signals are received, giving a total of 40 for both ascent and descent.

III. AUXILIARY EQUIPMENT

To transfer the barometer information into a signal that can be transmitted by radio, the circuit shown in Fig. 3 combined with the circuit shown in Fig. 2 of the following article were used.

In Fig. 3 the two small neon tubes form a relaxation oscillator with the condenser C. The time between pulses is determined by the high series resistance to ground. The barometer contact acts as a switch, going from 1 to 2, 3 to 4, and repeating, 1 to 2, 3 to 4 in succession. This causes the neons to change the time between flashes from about 2 to 3 to 4 seconds. When the received signal thus changes rate, the pressure is known.

IV. TESTS AND CALIBRATION

In calibrating, the pressure was reduced at about the same rate to be expected during a flight. This is important to minimize effects resulting from hysteresis in the metal. Similarly, the pressure was increased according to the expected rate of descent of the instrument. Pressures were determined to ± 0.2 mm of Hg.

Because of the large force required to expand the bellows, together with the small frictional force of the

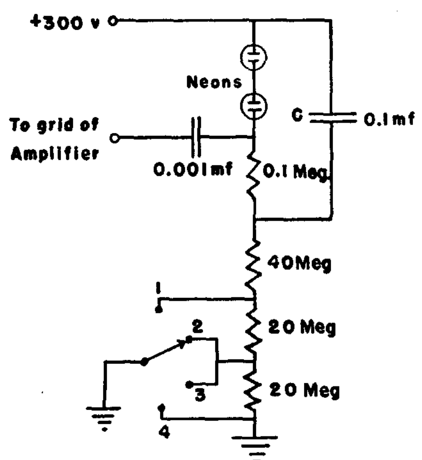

FIG. 3.

contact, there was no measurable effect caused by friction. Cooling the whole instrument of 0°C showed no measurable effect.

V. PERFORMANCE

This barometer is particularly suited for balloon ascents where the rate of rise and fall are approximately constant. This will be so where two balloons are used, one bursting at the maximum height, leaving the other to return the apparatus to earth. In such a case, if the logarithm of the pressure is plotted *vs* the time, the points may be connected by straight lines. Two straight lines with a bend at about the base of the stratosphere are nearly sufficient. If the points for such a plot do not lie on a straight line at high altitudes, experience has shown that the barometer is at fault. The intersection of the two straight lines at high altitudes on the ascent and descent give the time of bursting of the one balloon. On the occasions when the bursting has been observed visually, the two times have agreed very well.

In Fig. 4 is shown a typical record taken on August 6,

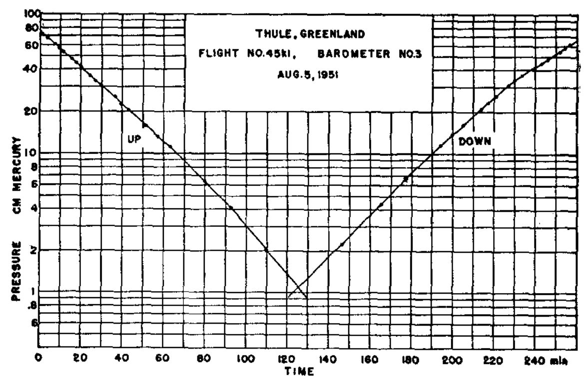

FIG. 4.

1951, at Thule, Greenland. In this case three straight lines on the ascent and descent are sufficient to fit the points very well.

Perhaps the best criterion of the operation of the device is the comparison of simultaneous flights made at Bismarck and Thule, Greenland. The fluctuations in the cosmic-ray intensity, as measured at both places, were of the order of 5 percent from day to day. If the flights made on August 3, 4, 5, and 6 at both stations are taken, and it is assumed that the fluctuations are simultaneous at both places, and the flights at Thule are corrected for the fluctuations, as measured at Bismarck, then the four curves at Thule have a maximum difference at a given pressure of less than 1 percent, at altitudes above 50 000 ft. The root mean square difference is approximately 0.4 percent. This error involves errors in two barometers and two ionization chambers, not only during the flights but in their calibrations.

The author is indebted to Mr. Glenn Sligh for his skill in making the barometer units, and to Mr. Edward Stern who calibrated them all.